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THE ALGORITHM FOR DETERMINING THE OPTIMAL ANGLE OF THE SOLAR PANEL DURING THE DAY

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Annotation- The article deals with the movement of the solar panel in continuous mode of keeping track of the Sun by moving the angle and direction of solar panels placing. A motion algorithm of mobile panel keeping track of the Sun was developed.

Keywords- Solar panel, panel keeping track of the Sun, mobile panel, helioenergetics, alternative energetics.

The density of the solar energy which incident on the panel depends not only on the flux density of solar radiation, but also on the angle between the module and sun rays. In case if the absorber plate and the solar radiation are perpendicular to each other, the flux density of the radiation incident on the panel is maximal. As the angle is changing the resulting flux density of solar radiation is decreasing.

For evaluation of the optimal position of the solar cell it is necessary to consider the basic angle parameters: geographical coordinates of placing location, hour angle, solar declination angle, elevation angle, azimuth angle.

Hereafter we present a sequence of the the motion algorithm steps of mobile panel keeping track of the Sun. Figure 1 displays a control-flow chart of algorithm consisting of the following operations:

1 Setting in of input data, such as geographical coordinates of installation location (latitude, φ, longitude, λ), and the reference time;

2 Start of cycle from 1 to N;

3 Computation of number of days from the beginning of the year to the current time;

4 Computation of the local solar time [1]:

$$LST = LT + \frac{TC}{60},$$

where LT – current local time,

TC – time adjustment factor [1]:

$$TC = 4(\lambda - LSTM) + \eta,$$

η – equation of time [1]:

$$\eta = 9{,}87\sin 2B - 7{,}53\cos B - 1{,}5\sin B,$$

where

$$B = \frac{360}{365}(d - 81)$$

in degrees, and d – number of days from the beginning of the year.

LSTM – local standard time meridian [1]:

$$LSTM = 15^\circ \cdot \Delta T_{GMT},$$

ΔT_{GMT} – The difference between local time and Greenwich Mean Time in hours.

5 Computation of hour angle [1]:

$$\omega = 15^\circ(LST - 12).$$

6 Computation of declination angle [1]:

$$\delta = 23.45^\circ \sin B.$$

7 Computation of elevation angle [1]:

$$H = sin^{-1}(\sin\delta\, sin\varphi + \cos\delta\cos\varphi\cos\omega).$$

8 Computation of sunrise time and sunset time [1]:

$$\text{Восход солнца} = 12 - \frac{1}{15^\circ}cos^{-1}(-tan\,\varphi\, tan\,\delta) - \frac{TC}{60},$$

$$\text{Заход солнца} = 12 + \frac{1}{15^\circ}\cos^{-1}(-\tan\varphi\tan\delta) - \frac{TC}{60}.$$

9 If the hour angle ω < 0, then azimuth angle [1]:

$$A = cos^{-1}\left[\frac{\sin\delta\cos\psi - \cos\delta\sin\psi\cos\omega}{\cos\alpha}\right],$$

otherwise azimuth angle:

$$A = 360^\circ - cos^{-1}\left[\frac{\sin\delta\cos\psi - \cos\delta\sin\psi\cos\omega}{\cos\alpha}\right].$$

10 If the elevation angle H < 0, then the panel seats on a horizontal surface and is directed to the south (β = 0, ψ = 0), otherwise the panel is rotated relative to the horizon through $\beta = 90^\circ - H$ and relative to the south through $\psi = A$;

11 Evaluation of the next timepoint by adding of 1 minute to the current timepoint.

12 Repetition of the cycle N times.

As a result of work of this algorithm values of the panel rotation angles are computed every minute. Thus, solar radiation will always be perpendicular to the solar panel plane, thereby we obtain the maximum amount of solar energy.

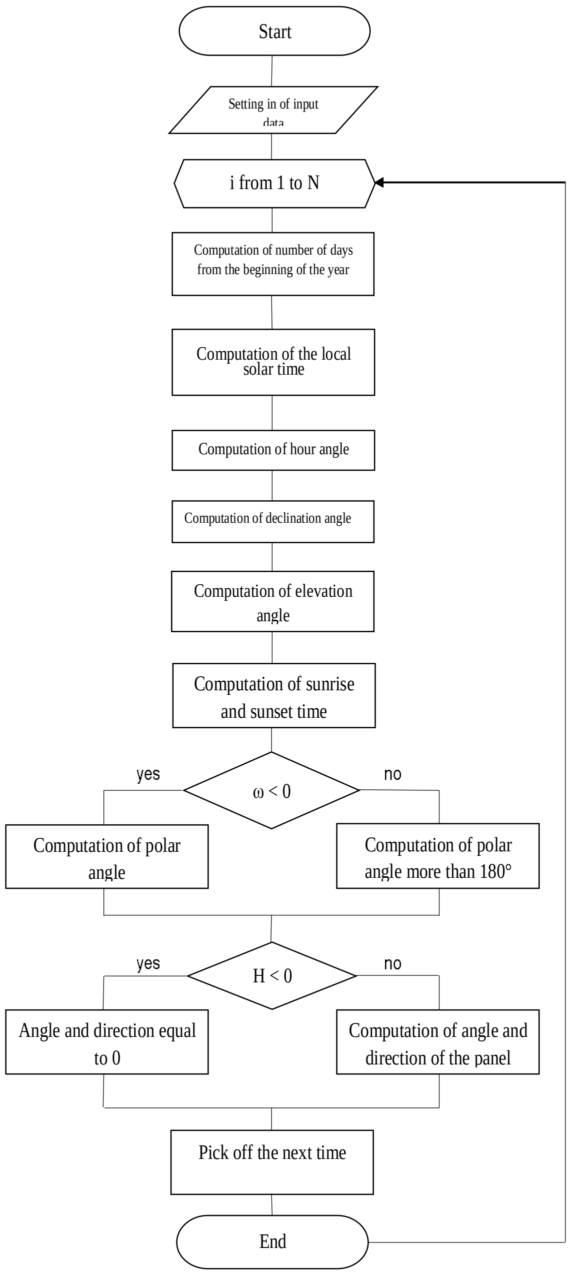


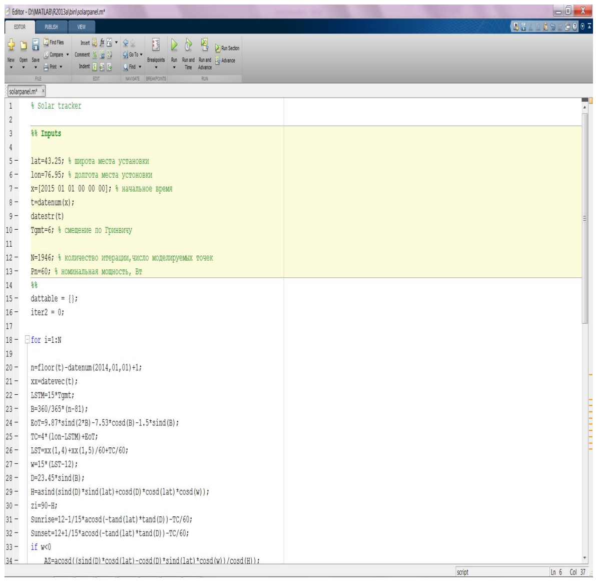
Figure 1 – Control-flow chart of motion algorithm of mobile panel keeping track of the Sun

The data inputs of the algorithm were:

– Almaty as a geographical location with coordinates 43.25° N and 76.95° E;

– the beginning of the time marking date was January 1, 2015.

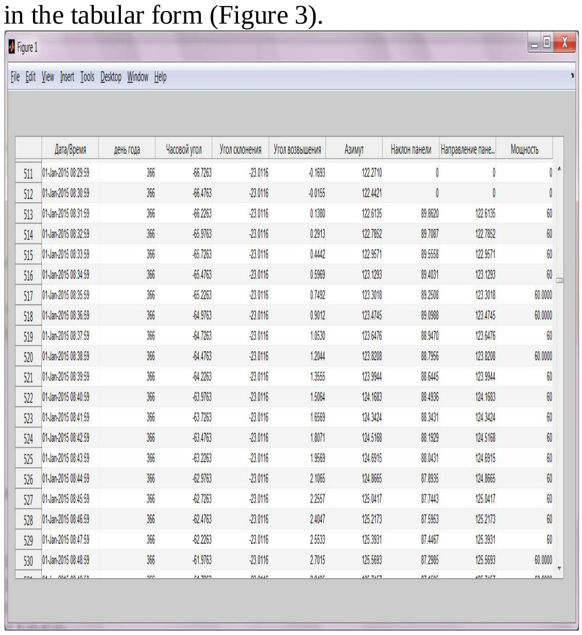
Figure 2 shows a software module of panel keeping track of the Sun in Matlab environment.



```
% Solar tracker

%% Inputs

lat=43.25; % широта места установки
lon=76.95; % долгота места устоновки
x=[2015 01 01 00 00 00]; % начальное время
t=datenum(x);
datestr(t)
Tgmt=6; % смещение по Гринвичу

N=1946; % количество итерации,число моделируемых точек
Pn=60; % номинальная мощность, Вт
%%
dattable = {};
iter2 = 0;

for i=1:N

n=floor(t)-datenum(2014,01,01)+1;
xx=datevec(t);
LSTM=15*Tgmt;
B=360/365*(n-81);
EoT=9.87*sind(2*B)-7.53*cosd(B)-1.5*sind(B);
TC=4*(lon-LSTM)+EoT;
LST=xx(1,4)+xx(1,5)/60+TC/60;
w=15*(LST-12);
D=23.45*sind(B);
H=asind(sind(D)*sind(lat)+cosd(D)*cosd(lat)*cosd(w));
zi=90-H;
Sunrise=12-1/15*acosd(-tand(lat)*tand(D))-TC/60;
Sunset=12+1/15*acosd(-tand(lat)*tand(D))-TC/60;
if w<0
    AZ=acosd((sind(D)*cosd(lat)-cosd(D)*sind(lat)*cosd(w))/cosd(H));
```

Figure 2 – A software module of the panel keeping track of the Sun

The result of the work of simulation model is shown in the tabular form (Figure 3).



	Дата/Время	день года	Часовой угол	Угол склонения	Угол возвышения	Азимут	Наклон панели	Направление пане...	Мощность
511	01-Jan-2015 08:29:59	366	-66.7263	-23.0116	-0.1693	122.2710	0	0	0
512	01-Jan-2015 08:30:59	366	-66.4763	-23.0116	-0.0155	122.4421	0	0	0
513	01-Jan-2015 08:31:59	366	-66.2263	-23.0116	0.1380	122.6135	89.8620	122.6135	60
514	01-Jan-2015 08:32:59	366	-65.9763	-23.0116	0.2913	122.7852	89.7087	122.7852	60
515	01-Jan-2015 08:33:59	366	-65.7263	-23.0116	0.4442	122.9571	89.5558	122.9571	60
516	01-Jan-2015 08:34:59	366	-65.4763	-23.0116	0.5969	123.1293	89.4031	123.1293	60
517	01-Jan-2015 08:35:59	366	-65.2263	-23.0116	0.7492	123.3018	89.2508	123.3018	60.0000
518	01-Jan-2015 08:36:59	366	-64.9763	-23.0116	0.9012	123.4745	89.0988	123.4745	60.0000
519	01-Jan-2015 08:37:59	366	-64.7263	-23.0116	1.0530	123.6476	88.9470	123.6476	60
520	01-Jan-2015 08:38:59	366	-64.4763	-23.0116	1.2044	123.8208	88.7956	123.8208	60.0000
521	01-Jan-2015 08:39:59	366	-64.2263	-23.0116	1.3555	123.9944	88.6445	123.9944	60
522	01-Jan-2015 08:40:59	366	-63.9763	-23.0116	1.5064	124.1683	88.4936	124.1683	60
523	01-Jan-2015 08:41:59	366	-63.7263	-23.0116	1.6569	124.3424	88.3431	124.3424	60
524	01-Jan-2015 08:42:59	366	-63.4763	-23.0116	1.8071	124.5168	88.1929	124.5168	60
525	01-Jan-2015 08:43:59	366	-63.2263	-23.0116	1.9569	124.6915	88.0431	124.6915	60
526	01-Jan-2015 08:44:59	366	-62.9763	-23.0116	2.1065	124.8665	87.8935	124.8665	60
527	01-Jan-2015 08:45:59	366	-62.7263	-23.0116	2.2557	125.0417	87.7443	125.0417	60
528	01-Jan-2015 08:46:59	366	-62.4763	-23.0116	2.4047	125.2173	87.5953	125.2173	60
529	01-Jan-2015 08:47:59	366	-62.2263	-23.0116	2.5533	125.3931	87.4467	125.3931	60
530	01-Jan-2015 08:48:59	366	-61.9763	-23.0116	2.7015	125.5693	87.2985	125.5693	60.0000

Figure 3 – The result of the simulation model

As a result of the work of algorithm for the evaluation of the optimal angle of the solar panel during the day, information on the hourly angle, declination angle, elevation angle, azimuth angle and an angle of panel rotation in space is provided, also information on the capacity of solar panel at each timepoint is provided.

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